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TITLE: THE LOS ALAMOS NATIONAL LABORATORY NEUTRON-NEUTRON SCATTERING PROGRAM

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THE LOS ALAMOS NATIONAL LABORATORY NEUTRON-NEUTRON SCATTERING PROGRAM

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ABSTRACT A theoretical and experimental program is underway to determine the feasibility of a measurement of the neutron-neutron scattering cross section of 10-12% uncertainty using small-angle, low center-of-mass energy, colliding neutron beams derived from a fusion-fission nuclear source. The neutron-neutron scattering length would be inferred from the measured cross sections. The general concept of the experiments and progress are discussed.

INTRODUCTION

The neutron-neutron scattering length, a_{nn}, is a quantity of fundamental importance in nuclear and particle physics that still eludes a direct measurement. In potential language, the scattering length reflects the cumulative effect of a potential over the entire range of interaction. For nucleon-nucleon scattering, the large magnitude of the scattering length ($|a_{nn}| \sim 17$ fm) comes from an almost-bound state in the spin-zero S-wave interaction and 3-4% changes in a_{nn} result from few-tenths % changes in the potential parameters. Therefore, the scattering length is quite sensitive to small components of the interaction among nucleons, such as Coulomb and three-body forces. As a result of its high sensitivity to the potential, the scattering length is a direct measure of the charge symmetry of forces between nucleons. Recent speculations based on simple quark-bag-model considerations have also related differences in the p-p and n-n scattering lengths to differences in the masses of the up and down quarks in nucleons. Despite the fact that Coulomb corrections must be applied to obtain the proton-proton scattering length, its value, $a_{pp} = -17.1 \pm .2$ fm, is far better determined than that of a_{nn}. Recent indirect measurements of a_{nn}, in which the two neutrons are produced at low relative energies in the multibody final states of various reactions, give values that disagree by four standard deviations, and lie on either side of a_{pp}, giving no clear indication of charge symmetry breaking in the nucleon-nucleon force. Theoretically, a_{nn} is expected to exceed a_{pp} by about 1 fm due to charge symmetry breaking. The situation is summarized in Figure 1, which is taken from the work of Gabioud, who performed the latest ^{2}H (Π^-, γ)nn measurements.[1] The dashed horizontal line is a "world average" (-16.6 + 0.6 fm) of the kinematically complete experiments, and the last point (-18.6 ± 0.45 fm) is Gabioud's value

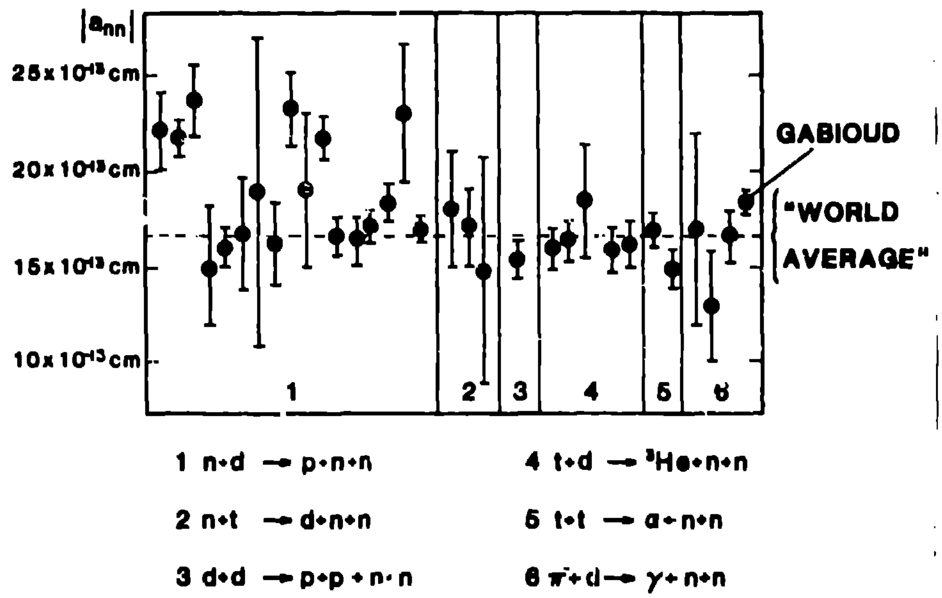

Figure 1. Distribution of n-n scattering lengths. They run chronologically left to right.

There are two conflicting theoretical views of the inferred a_{nn}. The extraction of a reliable a_{nn} from the multibody final state data must utilize full-blown, three-body Faddeev scattering theory.[2] On the other hand, some believe the extraction of a_{nn} from the Π^-d→γnn data suffers from inadequate considerations of pion distortion, meson-exchange currents and lack of consistency of gauge invariance.[3] Clearly a direct measurement of a_{nn} using colliding neutron beams circumvents all of these problems.

Dickenson and Bowman[4] discussed schematically an experiment in which neutron beams would be produced by exposing uranium plates to 14 MeV neutrons derived from a thermonuclear source. Moravcsik[5] reported a computer study showing the sensitivity of a_{nn} to the potential parameters. Our computer studies indicate that 10% cross-section measurements at 50 neutron energies between 38 and 22 keV (E_{cm}) would determine a_{nn} to better than 3%.

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N-N SCATTERING EXPERIMENT

The general concept of the experiment is shown in Figure 2. Neutrons from the source will transport through two heavily shielded, collimated, evacuated, intersecting lines-of-sight (LOS) to a collision volume in an evacuated tank. For simultaneous beams, collision kinematics dictate that all n-n scattered neutrons will be confined within a forward right circular cone whose surface is generated by rotating the LOS's about the axis of symmetry. Those neutrons scattered along the edge of the cone will be monoenergetic. By placing pairs of identical detectors, one just inside the cone surface and one just outside, the inside detector signal current will consist of nearly monoenergetic scattered neutron foreground plus background and the outside detector signal current will be background only. The uncollided neutrons are transported through two LOS's to two time-of-flight, recoil-proton spectrometers which are used to determine the respective differential velocity spectra $N(\nu_i)$ at the collision volume. These neutrons will be transported further to a CH_2 scatterer in one LOS and a C scattered in the other LOS in good geometry. The attenuated neutron flux in each LOS is then measured and the n-p cross section is inferred. This provides a check on the spectrometer experiments. Signal currents from the n-n scattered neutrons and background neutrons are generated in scintillator-photomultiplier neutron detectors positioned as described earlier. The scattering system is laser aligned before source zero time. The neutron beam profile at the scattering volume is determined via an imaging experiment. The entire scattering experiment is positioned inside of an extremely rigid pressurized tank 2.4m diameter by 36m long. This tank in turn sits on an I-beam structure. The n-n scattering cross section is extracted from a scattering integral and the a_{nn} from the effective range approximation.

This small-angle (3.8^{o}), colliding neutron beam experiment has four paramount features: (1) The entire pulse of n-n events is thrown sharply forward into a very narrow kinematic cone with high concentration of n-n events near the edge of the cone, (2) the n-n detector signal to isotropic background varies as the ratio $2/(1-\cos\alpha)=3600/1$, (3) CM collision energies of 38-4.4 keV are produced for approaching neutron energies, in the laboratory system, of 14-2 MeV. The low CM collision energies guarantees S-wave scattering which simplifies the extraction of a_{nn}, (4) The n-n scattering takes place at low CM energies while the detection of the n-n scattering events takes place at high laboratory energies. Thus, the detected neutrons outrace the background neutrons produced near the scattering volume.

EXPERIMENT STATUS

The following concepts have been established, ie: 1. Kinematic

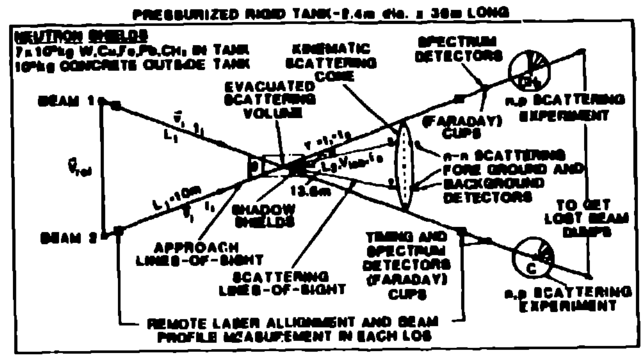

Figure 2. N-N Scattering geometry

equations for small-angle, colliding neutron beams produced by simultaneous (1-2 ns) and nonsimultaneous (4-8 ns) beams; 2. Calculation of the scattering volume produced by colliding neutron beams emanating from a point source; 3. Monte Carlo calculations of the diffuse-boundary, scattering volume produced by colliding neutron beams emanating from a finite size source with neutron penetration of the collimation systems; 4. N_N interaction rates, detector currents and locations, time and energy dispersion, and # neutrons/energy resolution width, for a point and finite size source, scattering volume and detectors; 5. Unique current signatures from the n-n scattering foreground and background detectors; 6. Uncertainties in measuring 10-12% n-n scattering cross sections; 7. Many successful tests of the TOF recoil-proton spectrometers, and overall simultaneous operation of hundreds of wide-band oscilloscopes and computer-controlled, digital data recording systems; 8. Three-dimensional design of the entire geometrical system using color graphics computer-aided design; 9. Monte Carlo simulation of radiation transport through the LOSs, shielding, scattering tank, shadow shields, re-emergent neutron cavities and beam dumps with the production of foreground signals from the LOSs and backgrounds from the shielding, etc.

EXPERIMENT SCHEDULE

1. Test of source and simultaneity - 1986.
2. Proof of principle test - 1987.
3. Main n-n scattering experiment - 1988.

REFERENCES

1. B. Gabioud, et al, Phys. Lett. 103B, 9 (1981).
2. R. Thayler, et al, Private Communication, March (1984).
3. Z. J. Cao and W. Y. P. Hwang, Phys. Rev. C 29 (1984).
4. W. C. Dickenson and C. D. Bowman UCRL 70376 (1967).
5. M. J. Moravcsik, Phys. Rev. 136, B624 (1964).